

THE INTERPRETATION OF TOTAL COLIFORM LEVELS IN
RECREATIONAL LAKES IN THE DISTRICT OF MUSKOKA

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SUMMARY

Total coliform bacteria (TC) were determined in Muskoka Lakes from 1971 to 1974 inclusive, by a count of dark red colonies with sheen on M-endo LES agar. TC densities ranged from 3 to 1,610 per 100 ml, with the largest seasonal variations in lakes of high trophic status. Maximum survey values were found mainly in the summer but occasionally occurred in the spring or fall. Maximum TC levels regressed significantly with mean summer chlorophyll (Chl a) and depth (Z) ($R = 0.9258$)

$$\text{LOG}_{10} \text{ TC (Max)} = -0.67 + 1.91 \text{ LOG}_{10} \text{ ChL } \underline{a} + \text{LOG}_{10} \text{ Z (Max)}.$$

These data were presented as a basis for the comparison of lakes using bacteriological values. TC levels also correlated significantly with fecal streptococcus levels in lakes. A change in the proportions of fecal bacteria upon entering the lakes was detected by comparing correlations of bacteria at point inflows and in the main body of water. Total coliforms may be retained as an additional parameter of fecal pollution at point inflows in the summer only. Maximum survey levels of total coliforms in the main body of water seemed best explained in terms of lake trophic status.

PREFACE

Small freshwater lakes in Ontario were examined from 1970 to 1974 inclusive for the Ontario Ministry of the Environment Recreational Lakes Program. The objectives for bacteriological studies were to document the present bacteriological water quality of a number of developed recreational lakes and of one undeveloped lake. This was achieved by determining the density and distribution of fecal bacteria, and the location and sources of major bacterial inputs, in these lakes. The program provided much needed information in the field of bacteriological limnology. Reports on individual lakes were completed by 1975.

The purpose of future studies will be to determine the relationship between lakeshore development and the bacterial densities in lakes. The project to examine this relationship, known as Lakeshore Capacity, requires, at the outset, a reevaluation of the traditional bacteriological water quality parameters. This report is one of a series in which such conclusions and new approaches to future studies will be derived from the survey data.

INTRODUCTION

The total coliform group comprises all of the aerobic and facultatively anaerobic, gram-negative, nonsporeforming, rod shaped bacteria which ferment lactose with gas formation within 48 hours at 35°C. The method of determining total coliforms in the recreational lakes under study was a total count of dark red colonies with sheen on M-endo LES agar (1). A few other closely related bacteria produce sheen colonies on this medium (3). As the coliforms were not confirmed by additional tests, such bacteria were included in the total coliform estimations, but were not expected to contribute large errors. The bacteria which grow on m-Endo's medium were also identified in a previous M.O.E. study (2).

In bodies of water total coliforms are used as indicators of waste pollution (1), but coliforms may come from unpolluted soil and water (5), and so their numbers are not reliably related to the degree of pollution. An important problem, that of describing the relationships between different coliform types and their natural habitats or pollution sources, is unsolved. Coliforms are known to grow in nutrient rich waters, and for this and other reasons, they are considered by some to be an inadequate index of water quality (7).

During the Recreational Lakes Program, bacteriological water quality was measured by three parameters, total coliform, fecal coliform and fecal streptococcus, which were interpreted together to avoid the possible errors alluded to above. It appeared from this experience that, of the parameters, fecal coliforms gave the most reliable index of lake water quality. Research interest has now focused on this bacterial type and method refinements are under consideration, for example, m-TEC medium (6).

Total coliforms are a group of heterotrophic bacteria which are distinguished by their use as indicators of water pollution. The mathematical relationships which have been proposed to explain heterotrophic bacterial levels in Muskoka Lake water (11) have not been developed for total coliform bacteria. This report gives an overview of total coliform levels in Muskoka Lakes, and describes the relationship of total coliforms with some other water quality parameters. Total coliforms appear to be a useful index of water quality in Recreational Lakes, and a new interpretation is presented here.

Methods

Selection of Lakes:

All available data from lakes in the District of Muskoka were used for this report, and nearby additional Simcoe lakes, Bass and St. John, were added to give better representation from lakes of higher trophic status.

Surveys:

Lakes were surveyed for five consecutive days, in the spring, summer, and often the fall of the year, at a number of locations considered to be representative of shoreline features and development. In addition, one or two sampling locations were placed in the middle of the lake. Samples were taken one metre from the surface 10-15 meters from shore, and an additional sample at a mid-lake location was taken one metre from the bottom.

Bacterial Enumeration:

- 1) Total coliform bacteria were determined as a count of dark red colonies with sheen grown on a membrane filter with M-endo LES agar (1).
- 2) Fecal coliform bacteria were determined as a count of acid producing yellow to yellowish-green colonies grown on a membrane filter with McConkey broth at 44.5°C.

- 3) Fecal streptococcus bacteria were obtained from a count of pink or red colonies grown on a membrane filter with M-enterococcus agar (1).
- 4) Heterotrophic bacteria were obtained from a total count from surface inoculated plates of a modified Foot and Taylor medium (11).

Data Processing:

These data were evaluated by statistical techniques in the following manner. The geometric mean, and standard deviation were calculated for the values of each of the three bacterial types at every station, providing concise valid data. Statistically significant variations in the bacterial densities between stations, or groups of stations, was determined by a One-Way Analysis of Variance and Bartlett's Test of Homogeneity. By these means the data from each station were tested against that of every other station until all stations with similar geometric mean densities were separated into groups (A, B, etc.). Sampling locations in the main body of water usually formed a large group (Group A), whereas sampling locations at the mouth of streams were rejected from this group and were treated separately.

Chlorophyll a

Water samples, collected for the Limnology Section, from mid-lake stations through the photic zone, were stabilized with MgCO_3 suspension, filtered onto a membrane filter of 1.2 μm pore size, then stored on ice. Chlorophyll a was determined by the Water Quality Chemistry Section using the method of Richard and Thompson (19). These samples were taken daily, with the bacteriological samples, in spring, summer and fall, then the results were expressed as an arithmetic mean summer Chl a concentration.

RESULTS

Total coliform densities in the study lakes ranged from 3 to 1,610 per 100 ml, with the largest seasonal variations found in lakes of high trophic status (Table 1). Maximum survey total coliform densities were found mainly (11 of 17 lakes) in the summer, but a smaller number (6 of 17 Lakes) were found in spring or fall. The Recreational Criteria (10) were exceeded by maximum values in three eutrophic lakes, Maclean Lake, Stewart Lake and Muskoka Bay.

The total coliform levels in the undeveloped lake, Jerry Lake, were low, but the lowest levels recorded, 3 TC per 100 ml, were found in Skeleton Lake in the spring survey. Skeleton Lake was the deepest lake in this group (Table 1).

Spring and summer total coliform levels were not correlated well enough to predict one season's survey values from the other (results not illustrated).

Correlation coefficients were calculated for pairs of water quality parameters for the main body of the lake and point inflows to the lakes (Table 2). $\log_{10}$ transformed data gave more significant results than the original data. Total coliform levels at point inflows to the lake were highly correlated with the other bacterial parameters except spring fecal coliforms. In contrast, in the main body of the lake, total coliform densities correlated only with fecal streptococcus levels, and this was likely due to the correlation of both these bacterial types (TC and FS) with another independent variable, chlorophyll (Chl a). It was also observed that correlations of bacterial values within individual lakes were greater and more often statistically significant than the correlations across the group of lakes (Table 3).

Total coliform densities for the main body of the lakes were significantly correlated with Chl a and depth (Z) (Table 4). The relationship between total coliform levels and trophic status of lakes was described by the following regression equations:

TABLE 1

GEOMETRIC MEAN (GM) TOTAL COLIFORM DENSITIES (TC/100 ML) FOR THE MAIN BODY OF LAKES

NO.	LAKE	SPRING	SUMMER	FALL	SPRING/SUMMER	MAXIMUM SURVEY	DEPTH		Chl <u>a</u>
		GM	GM	GM	GM	GM	Z max (ft.)	Z (ft.)	(ug/l)
1	Leonard '71	13	14	51	13.49	51	50.0	23.6	1.8
2	Bala Bay '71	10	20	24	14.13	24	122.0	?	1.7
3	Kahshe '71	38	11	326	20.45	326	66.0	28.3	3.3
4	Muskoka Bay '71	-	1600	-	-	1600	56.6	23.	13.2
5	Skeleton '72	3	63	-	13.75	63	216.0	99.9	0.9
6	3-Mile '72	8	37	-	17.2	37	14.4	11.3	3.0
7	Jerry '72 ‡	46	56	51	40.32	56	116.6	46.0	2.0
8	Jerry '73 ‡	8	51	11	20.19	51	116.6	46.0	2.0
9	Harp '73	49	68	25	57.72	68	119.9	47.6	2.8
10	Maclean '73	1520	41	23	249.7	1520	35.0	17.3	15.5
11	Peninsula '73	47	75	-	59.37	75	112.0	29.3	1.9
12	Stewart '74	51	1610	-	286.5	1610	69.0	20.6	4.4
13	Brandy '74	46	102	-	68.5	102	23.0	11.7	5.5
14	Walker '74	72	77	-	74.46	77	50.0	17.3	1.6
15	Waseosa '74	35	8	-	16.73	35	63.0	23.0	2.8
16	Fox '74	45	9	-	20.12	45	49.0	17.6	2.1
17	Bass '74	58	335	-	139.4	335	45.0	12.0	6.4
18	St. John '74	105	396	-	203.9	396	25.0	15.5	12.4

‡ + Undeveloped Lake

TABLE 2
Correlation coefficients for Log₁₀ of pair of bacterial water
quality parameters for the main body of lakes and point inflows

Correlation between Bacterial parameters	<u>Source of data</u>	
	Main body of the lake	Many point inflows to the lake
Spring values		
TC vs FC	0.0186 NS	0.1605 NS
TC vs FS	0.4752 NS	0.4859 **
Summer values		
TC vs FC	0.3833 NS	0.6264 **
TC vs FS	0.7091**	0.5537 **

** Significant at P = 0.01

NS - Coefficient not significant at P = 0.05

TABLE 3

CORRELATION COEFFICIENTS FOR PAIRS OF LOG_{10} BACTERIAL WATER QUALITY
PARAMETERS FOR SAMPLING STATIONS WITHIN LAKES

	STEWART LAKE	THREE MILE LAKE
SPRING		
TC vs. FC	- 0.0045 NS	0.3338 NS
TC vs. FS	0.3364 NS	0.4395 *
SUMMER		
TC vs. FC	- 0.0319 NS	0.4938 **
TC vs. FS	- 0.5849 *	0.5166 **

* Significant, $P = .05$

** Significant, $P = .01$

NS Not significant, $P = 0.05$

TABLE 4

Correlation Coefficients of Log Geometric Mean (GM) Total Coliform
Density vs. Log Chl a

BACTERIOLOGICAL SURVEY VALUE	CORRELATION COEFFICIENT
Spring GM	0.7485**
Summer GM	0.5449*
Spring/Summer GM	0.7533**
Maximum Survey GM	0.7953**
<u>GM Spring/Summer x 10</u> <u>-</u> <u>Z</u>	0.7636**
<u>Max GM</u> <u>-</u> <u>Z</u>	0.8658**

** Significant, P = 0.01

* Significant, P = 0.05

$$\text{LOG}_{10} \left(\frac{\text{TC max}}{\text{Z (max)}} \right) = - 0.67 + 1.91 \text{ LOG}_{10} \text{ Chl } \underline{a} \text{ (R = 0.9258) - Fig. 1.}$$

$$\text{LOG}_{10} \left(\frac{\text{TC (spr./sum. G.M.)} \times 10}{\text{Z}} \right) = 0.56 + 1.52 \text{ LOG}_{10} \text{ Chl } \underline{a} \text{ (R = 0.7636)}$$

Further equations could be developed from the data in Table 4.

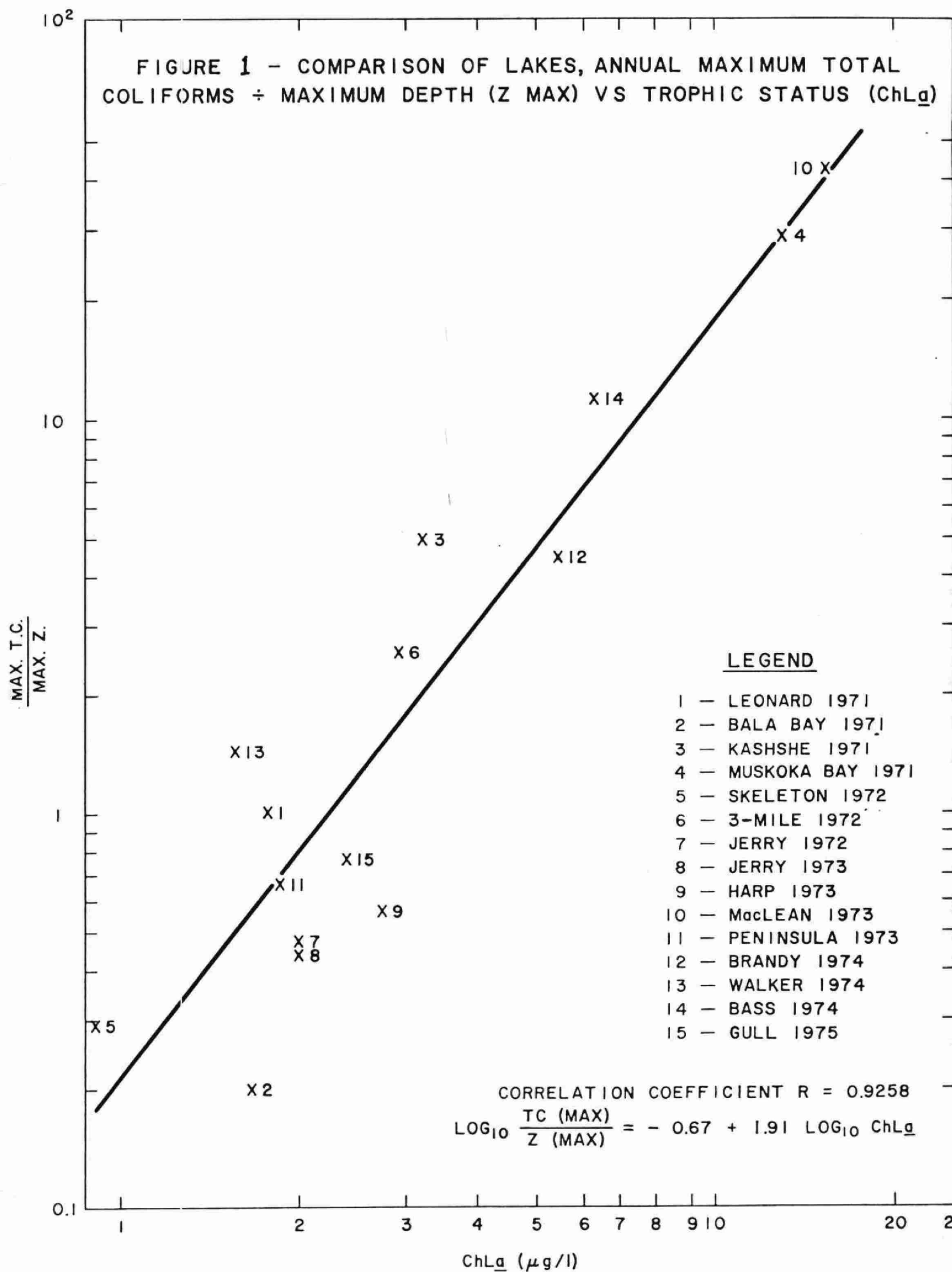
DISCUSSION

Variation in Total Coliform Levels

Large variations in total coliform levels were found in Muskoka Lakes and our present aim was to find a basis for these variations and to re-examine the water quality interpretation of total coliforms in recreational lakes.

Seasonal variations of total coliform densities in freshwater lakes show a prominent maximum in the period August to September. This was illustrated by a study in Lake Michigan (4), and Lake Ontario (A. Burger-unpublished results), as well as Harp Lake (17), and Jerry Lake (18) in Muskoka. Data for a whole year were, however, not available from the Recreational Lakes Program. From this previous work a total coliform maximum was expected in the summer or early fall, and was found in 14 of 17 lakes studied (Table 1). Two of the three remaining lakes which showed a spring maximum (Maclean, Fox) were shallow with rapid flushing rates.

FIGURE 1 - COMPARISON OF LAKES, ANNUAL MAXIMUM TOTAL COLIFORMS ÷ MAXIMUM DEPTH (Z MAX) VS TROPHIC STATUS (ChL_a)



Effect of Temperature and Nutrients on Total Coliform Levels

The growth of total coliforms in water is regulated by nutrient levels and temperature (15). Lake water temperature reaches a maximum in late August. The observed summer maxima of total coliforms are likely caused by high water temperatures. Without nutrients, however, elevated temperatures lead to more rapid death of the bacteria, for starved coliforms survive longer at low temperatures (9). High summer total coliform densities in lakes are therefore likely related to the nutrient content and temperature of lake water.

Relationship of Total Coliform to Lake Trophic Status

In a reservoir in England (21) total coliforms increased rapidly after an algal bloom, but it was not known if nutrients for growth were supplied by the algae or merely accompanied them. In Muskoka Lakes total coliforms correlated significantly with mean summer chlorophyll (Table 4), and the most likely explanation is that conditions for growth of coliforms were present in Muskoka Lakes, so that nutrients available to coliforms entered the lakes in reasonable proportion to the phosphorous which nourished the algae. It is also possible that leakage products from algae or degraded algae can nourish certain types of total coliforms. At present, it is not possible to decide if the relationship between total coliforms and algae (Chl a) is direct or indirect. A similar relationship between summer Chl a levels and total coliform densities was noted in lakes studied for the recreational lakes self-help program (12). The phosphorus input to Muskoka Bay was reduced in recent years with a corresponding reduction in algae (14). It would be interesting to resurvey Muskoka Bay for total coliforms and determine if new values are in proportion to the lowered chlorophyll levels.

In summary, we have observed that maximum total coliform levels in Muskoka Lakes, which are found largely in August and September and are therefore correlated with maximum lake water temperature, are also highly related to lake trophic status, as described by the following regression equation.

$$\text{LOG}_{10} \left(\frac{\text{TC (max.)}}{\text{Z (max)}} \right) = -0.67 + 1.91 \text{ LOG}_{10} \text{ Chl } \underline{a} \quad (R = 0.9258) \text{ (Fig. 1).}$$

Rearrangement showed this to be a multiple regression of the form:

$$\text{LOG}_{10} \text{ TC (max)} = -0.67 + 1.91 \text{ LOG}_{10} \text{ Chl } \underline{a} + \text{LOG}_{10} \text{ Z (max.)}.$$

It is difficult to explain why total coliform densities were related to the lake depth, but the above equation states that as lake depth increased, the total coliform levels were greater than would be predicted from the Chl a levels alone. Lake temperature is proportional to depth with deep lakes being colder lakes. It was noted earlier that coliforms survived better at cold temperatures so that coliform levels and depth could be related through lake temperature. A final conclusion awaits a more complex analysis.

Maximum depth was also related to trophic status in these lakes.

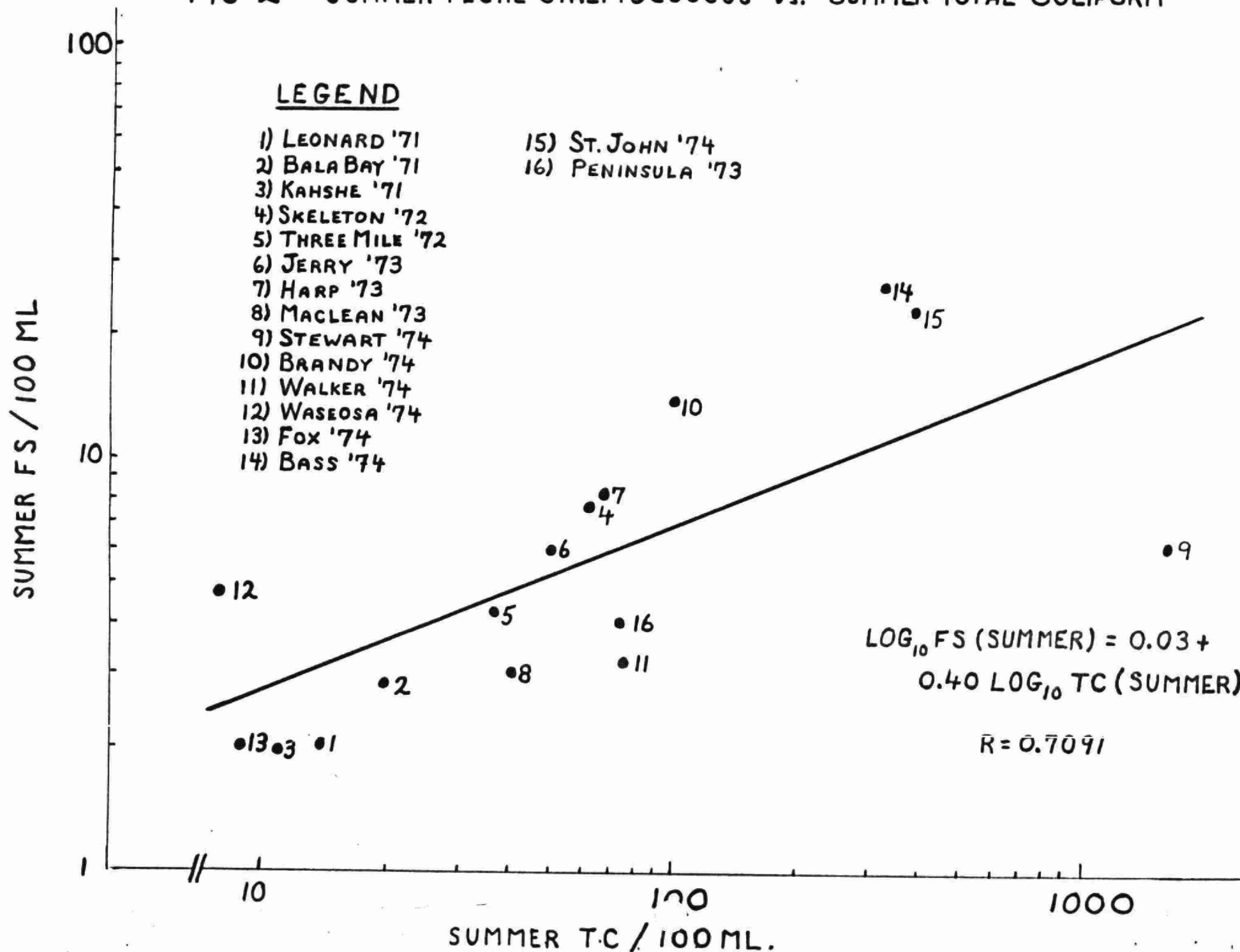
$$\text{LOG}_{10} \text{ Z (max)} = 2.04 - 0.51 \text{ LOG}_{10} \text{ Chl } \underline{a}, \quad (R = 0.5914), \quad P = 0.05.$$

Relationship between Total Coliforms and Other Water Quality Parameters

Correlations between total coliforms and other bacteriological water quality parameters are reported infrequently, but a few examples can be given (15) (12) (7). In Muskoka Lakes total coliforms correlated significantly only with fecal streptococci and then only in the summer. An improvement was found in this correlation for the main body of water over point inflows (Table 2). Accurate predictions could not be made from this relationship, though a rough estimate may be possible.

$$\text{LOG}_{10} \text{ FS (Summer)} = 0.03 + 0.40 \text{ LOG}_{10} \text{ TC (Summer)} \quad (R = 0.7091) - \text{Fig. 2.}$$

FIG 2- SUMMER FECAL STREPTOCOCCUS vs. SUMMER TOTAL COLIFORM



fully explained by lake trophic status and the residual information may be meaningful. Total coliform bacteria should not be considered to be fully derived from growth in the lake. A more complex analysis may uncover other relationships. The correlation of total coliforms and fecal coliforms does not imply redundancy, though this has been advocated (8), for in those cases where fecal coliform values are close to zero, a total coliform measurement is always possible and most useful. Relationships within the lake ecosystem form a complex web. Numbers of bacteria are therefore expected to be directly and indirectly related to measurements of some other organisms and substances. A parameter does not become redundant when it merely correlates with another, but only when it ceases to perform its function, or interest in it is lost. If total coliforms are redundant, it is because of the lack of correlation with fecal coliforms in lakes, and so the failure of its function as a lake indicator of sewage pollution, and not as a result of the correlations with Chl a. The idea of using total coliform levels as a measure of lake trophic status is too novel to be fully appreciated at present. A final decision on the redundancy of total coliform measurements cannot not be made immediately.

The Effect of Lake Processes on Total Coliform Relationships

Total coliforms were correlated with more bacterial parameters at point inflows than in the main body of the lakes (Table 2) and this indicated a change in the proportions of fecal bacteria (TC, FC and FS) after they had been washed into the lake. More correlations were maintained within lakes than across the group of lakes (Table 3) which further suggested that the factors influencing the bacteria were characteristic of the individual lakes. It is well known that bacteria are sensitive to changes in their physical and chemical environment. The most obvious lake characteristics which would affect bacteria were temperature and nutrient levels though there are likely others. The correlation of bacterial

Heterotrophic bacteria did not correlate with total coliforms. A correlation was expected as both parameters correlated with chlorophyll. There were only seven pieces of heterotroph data so that a high correlation coefficient was required before significance was obtained. This was likely the main reason for the lack of significance between HB and TC.

In support of this, it was shown that spring BKGD values, which were available for all lakes, correlated with spring TC densities for the main part of the lakes. This type of bacterium (BKGD) was used previously as a measure of heterotrophic bacteria (11). The BKGD, TC relationship was poor in the summer when BKGD levels rose by about 40 fold, however, in the spring the relationship was good: ($R = 0.8591$) (Fig. - 3).

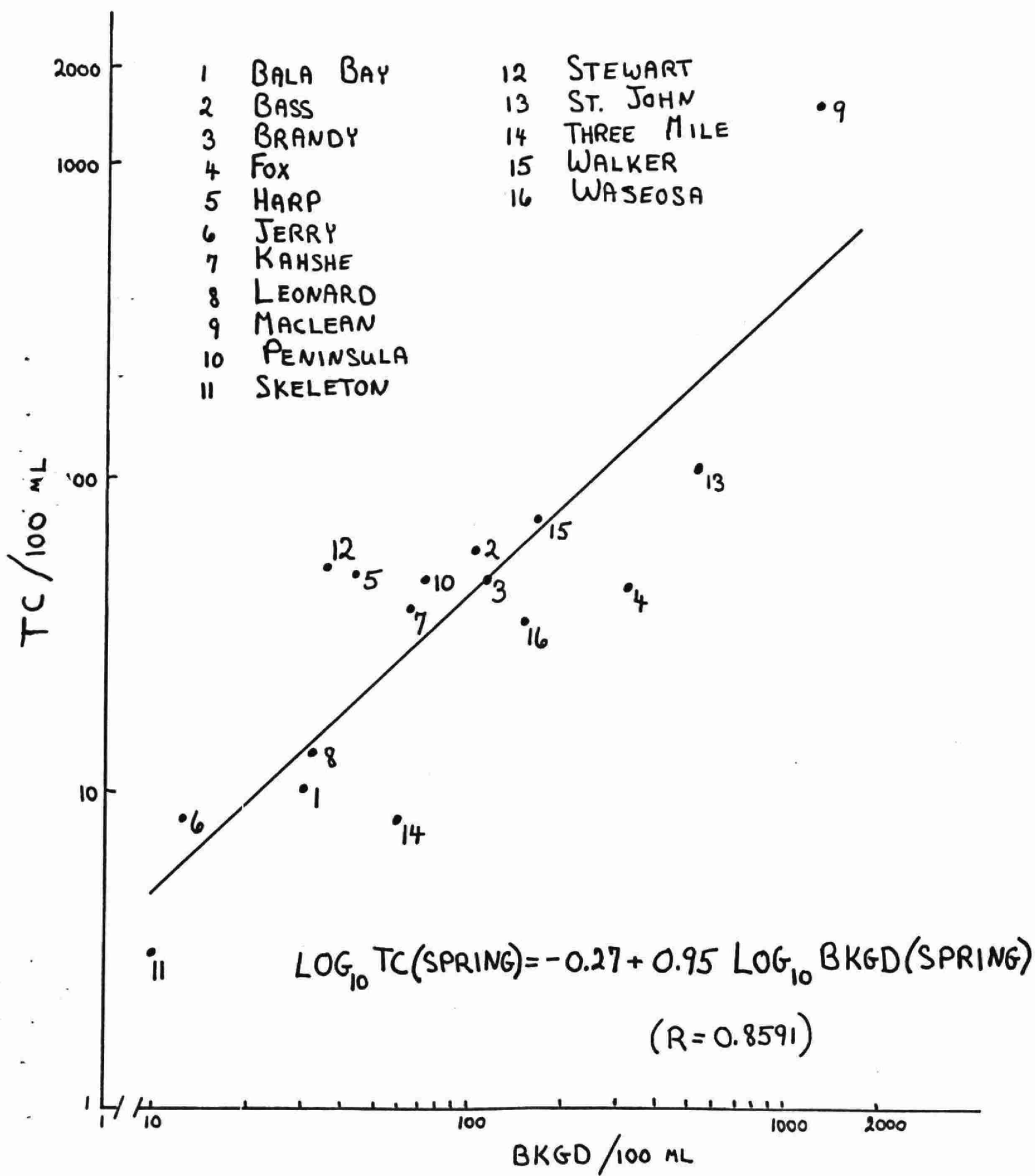
$$\text{LOG}_{10} \text{ TC (Spring)} = - 0.27 + 0.95 \text{ LOG}_{10} \text{ BKGD (Spring)}.$$

Fecal and total coliforms were correlated significantly at point inflows in the summer, but not in the spring, and not at all in the main body of the lake (Table 2). Fecal streptococci correlated significantly with total coliforms at point inflows in both spring and summer. Since fecal coliforms are the most reliable index of fecal contamination, total coliforms should not be used in a direct manner as a parameter of fecal pollution in lakes. However, they may be retained as a fecal indicator at point inflows during the summer.

Redundancy of Total Coliform Measurements

Total coliforms have now been correlated with summer fecal coliforms in streams, fecal streptococci, BKGD, and chlorophyll in lakes. The question arose; is the measurement of total coliforms redundant? Maximum total coliform values seem to be fully explained in terms of lake trophic status, and their use could be retained if a scale of comparison of lakes based on bacteriological measurements was required. The seasonal mean total coliform values were not

FIG 3 - SPRING TOTAL COLIFORMS vs SPRING BKGD



in streams initially reflected a common source of bacteria (possible fecal), while the correlations of bacterial values within lakes reflected the lake trophic status. The proportions of bacteria were likely modified by each lake and the changes were detected by an examination of the correlation coefficients. This important conclusion was not found in the literature though it was not really unexpected. The data supporting it was somewhat slender and the subject will be examined as soon as possible in another set of lakes.

The bacteria from sewage pollution are omitted, usually for lack of a framework of interpretation, from studies of the effects of eutrophication of lakes on bacterial microflora. We have shown how at least one of these bacteria (TC) can be influenced by nutrient levels in lakes.

Bacteriological Water Quality of Recreational Lakes in Muskoka

Many cottagers use their lake as a source of drinking water so it is fitting that lake water quality be evaluated with both the drinking water and Recreational Use Criteria, which are quoted in TABLE 5. Lakewater quality was rated by how the total coliform values exceeded the various criteria (TABLE 6). Three lakes, Muskoka Bay, Maclean and Stewart lakes exceeded the permissible Criteria for private water supplies as well as the Recreational Criteria for total coliforms. Those eutrophic lakes examined for heterotrophic bacteria exceeded the Criteria for total bacteria in public surface water supplies as well (11). None of the lakes surveyed were suitable as sources of drinking water without prior sterilizing treatment.

Fecal coliform levels in the study lakes were low. The high total coliform levels, in eutrophic lakes studied, were likely due to growth of total coliforms in the lakes rather than heavy sewage pollution. These high total coliform levels, however, may emphasize a related problem for a recent M.O.E. study (20) showed that the ease of isolation of Pseudomonas aeruginosa, a bacterium which may cause ear and eye infections, increased in lakes of high trophic status.

TABLE 5

BACTERIOLOGICAL CRITERIA FOR DRINKING WATER AND RECREATIONAL USE *

BACTERIA	CRITERIA FOR PRIVATE WATER SUPPLIES			PUBLIC SURFACE WATER		RECREATIONAL USE
	Permissible Criteria		Desirable Criteria	Desirable Criteria	Permissible Criteria	
	Chlorination only	Chlorination and Filtration	No Treatment			
Total Coliforms	100/100 ml	400/100 ml	0/100 ml	100/100 ml	5,000/100 ml	1,000/100 ml
Fecal Coliforms	10/100 ml	40/100 ml	0/100 ml	10/100 ml	500/100 ml	100/100 ml
Fecal Streptococci	1/100 ml	4/100 ml	0/100 ml	1/100 ml	50/100 ml	20/100 ml
Total Bacteria	1,000/100 ml	4,000/100 ml	10/100 ml	1,000/100 ml	10 ⁵ /100 ml	-
Clostridia (in water)	0/100 ml	4/100 ml	0/100 ml	0/100 ml	50/100 ml	-

* For conditions of sampling and other details consult ref. (10)

TABLE 6

RATING OF LAKES - BY EXCEEDING DRINKING WATER AND RECREATIONAL CRITERIA FOR TOTAL COLIFORMS
CRITERIA FOR TOTAL COLIFORMS

NO.	LAKE	Criteria for Private Water Supplies			Public Surface Water Criteria		Recreational Criteria
		Desirable	Permissible		Desirable	Permissible	
		No Treatment	Chlorination only	Chlorination & Filtration			
1	Leonard '71	+					
2	Bala Bay '71	+					
3	Kahshe '71	+	+		+		
4	Muskoka Bay '71	+	+	+	+		+
5	Skeleton '72	+					
6	3-Mile '72	+					
7	Jerry '72	+					
8	Jerry '73	+					
9	Harp '73	+					
10	Maclean '73	+	+	+	+		+
11	Peninsula '73	+					
12	Stewart '74	+	+	+	+		+
13	Brandy '74	+	+		+		
14	Walker '74	+					
15	Waseosa '74	+					
16	Fox '74	+					
17	Bass '74	+	+		+		
18	St. John '74	+	+		+		

+ = Criteria For Total Coliform Bacterial Exceeded For Some Portion Of The Year

Inhibition of Total Coliform Colony Formation by Background (BKGD) Colonies

Total coliform colony formation appears to be inhibited by certain background bacteria (BKGD). The numbers of BKGD colonies on the membrane filter can be reduced by use of less sample which leads to the appearance of greater numbers of total coliforms. An example is illustrated using data from the 1975 survey on Lake Manitouwabing (TABLE 7), and the effect has been noted on many other lakes.

Total coliform levels in four lakes, Kahshe, Maclean, Waseosa, Fox, were lower in summer than in spring against the normal trend (TABLE 1). BKGD levels in these lakes was also very high (11), and the conditions for inhibition of total coliform colony formation may have been present. Not enough is known yet to allow a prediction of the degree to which total coliform measurements were depressed. The high BKGD levels in Bass and St. John Lakes need not have inhibited total coliform measurements as the accompanying densities of total coliforms were higher, allowing the use of less sample, and so the production of less BKGD on the membrane filter used for water analysis.

Future Uses of the Total Coliform Relationships

A) Comparison of Lakes

A method of comparing lakes based on a regression of HB on Chl a has been proposed (11). One disadvantage was the lack of past data, which can largely be overcome by use of total coliform values as the basis of comparing lakes. The method was used in a recent water quality report (16) in a manner similar to Figure 1 using the following regression:

$$\text{LOG}_{10} \frac{\text{TC (max)}}{\text{Z (max)}} = -0.67 + 1.91 \text{ LOG}_{10} \text{Chl } \underline{a}$$

It is considered desirable to develop a method of comparing lakes using only bacteriological parameters, and a method utilizing all three bacteriological water quality parameters is being studied.

TABLE 7

**DILUTION EFFECT ON RECOVERY OF TOTAL COLIFORMS FROM LAKE
MANITOUWABING, 1975.**

Background Bacteria and Total Coliforms per 100 ml

Sample	Volume	1 ml	5 ml	10 ml	25 ml
Sample No.	Bacterial Type				
1	TC** BKGD	1,600 12,000		600 TNTC*	
2	TC BKGD			250 6,000	64 TNTC
3	TC BKGD			220 TNTC	64 TNTC
4	TC BKGD		1,920 5,180	270 TNTC	
5	TC BKGD		340 3,400	70 TNTC	
6	TC BKGD		100 TNTC		8 TNTC
7	TC BKGD		200 10,240	50 TNTC	
8	TC BKGD		40 TNTC	0 TNTC	

* = TNTC - Density unknown, too numerous to count

** = TC - Total coliform colonies

BKGD = - Background colonies

B) Lakeshore Capacity

An early objective of the Lakeshore Capacity Study is the reexamination of the traditional bacteriological water quality parameters (13). The reevaluation was initiated in this report and important conclusions were indicated which altered the interpretation of total coliform levels in lakes, and uncovered some new relationships between total coliform levels and other parameters of water quality.

Maximum survey levels of total coliforms can be estimated from mean chlorophyll levels and the data displayed in Figure 1, then linked to lakeshore development by the method previously for heterotrophic bacteria (11). However, this method should be considered a method of last resort as more direct relationships will be discovered in the Lakeshore Capacity Study. The results reported here are better used for developing an understanding of the effect of lake processes on bacteria than for predictive purposes.

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